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Title: Understanding Discrete Fracture Networks Through Spectral Graph Theory

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Report

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Los Alamos NATIONAL LABORATORY

Understanding Discrete Fracture Networks through Spectral Graph Theory

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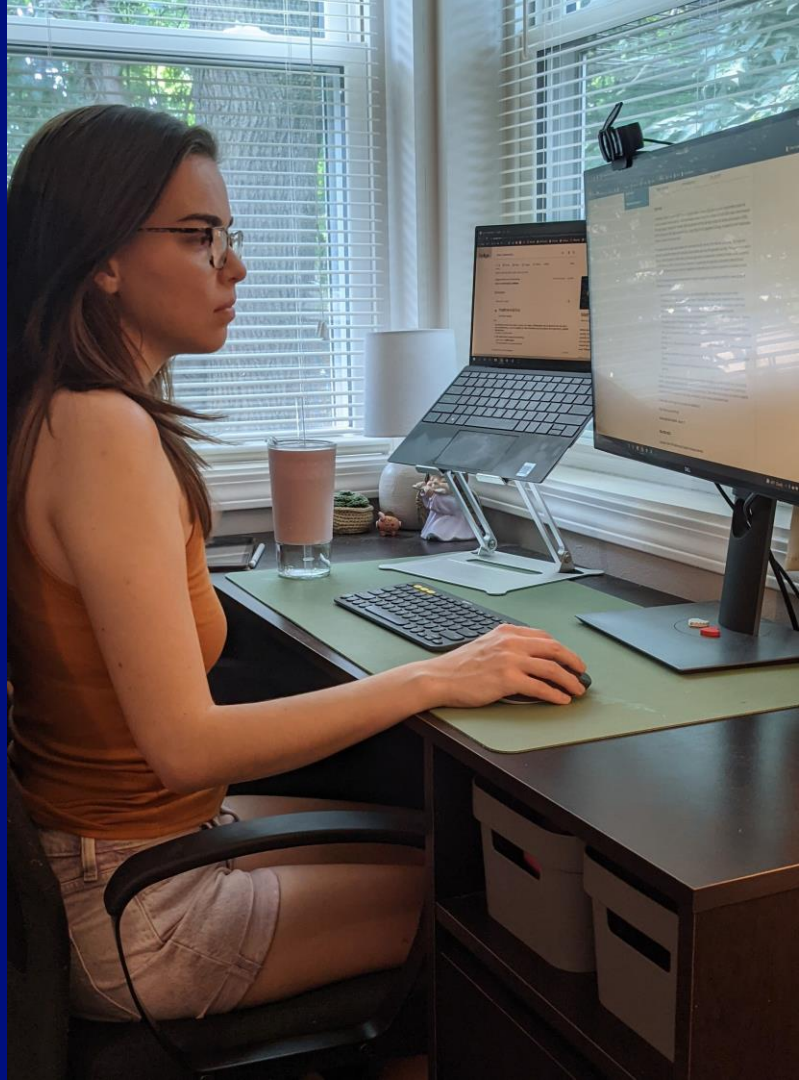
About me

- PhD student in mathematics at UIUC
- Study geometric topology and geometric group theory
- Summer internship with Los Alamos National Laboratory, Computational Earth Science Group
- Internship mentors: Jeffrey Hyman, Matt Sweeney, Aric Hagberg



Working at home during my virtual internship

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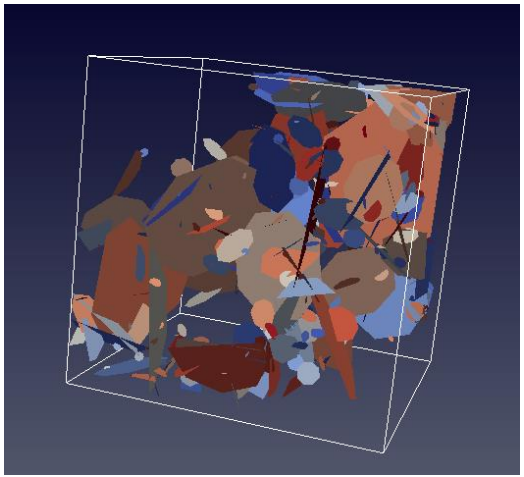
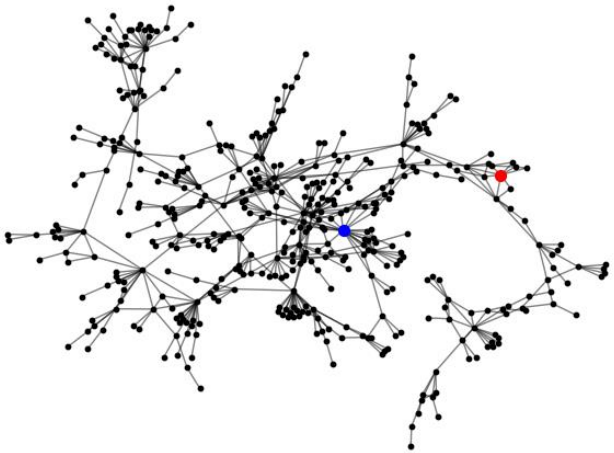
Big Idea

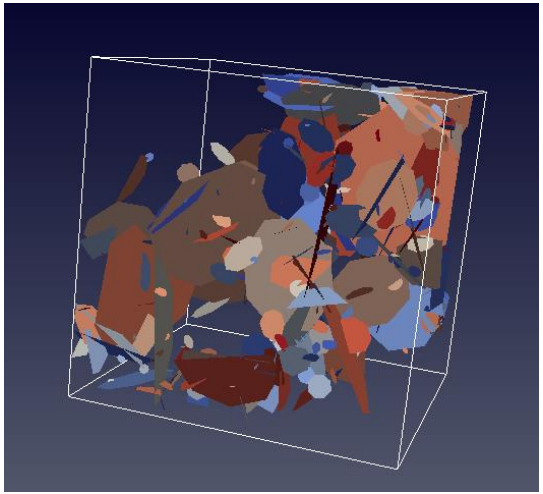
- Use spectral graph theory to understand fracture networks to reduce computational effort.





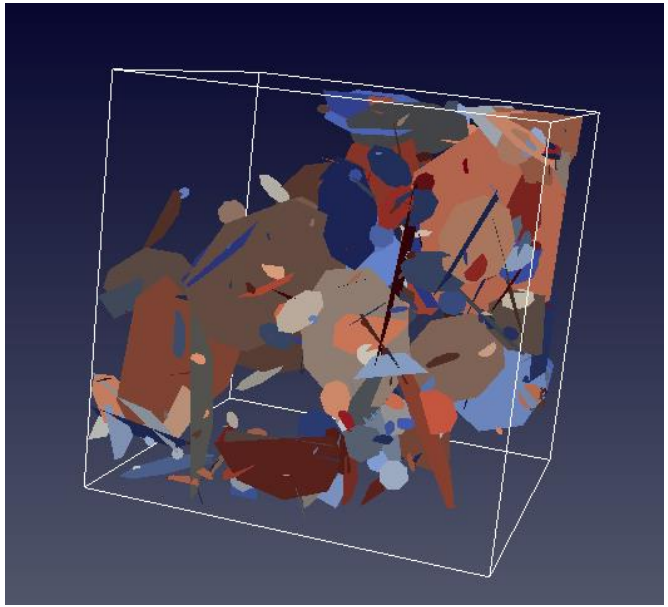
Discrete Fracture Networks (DFNs)

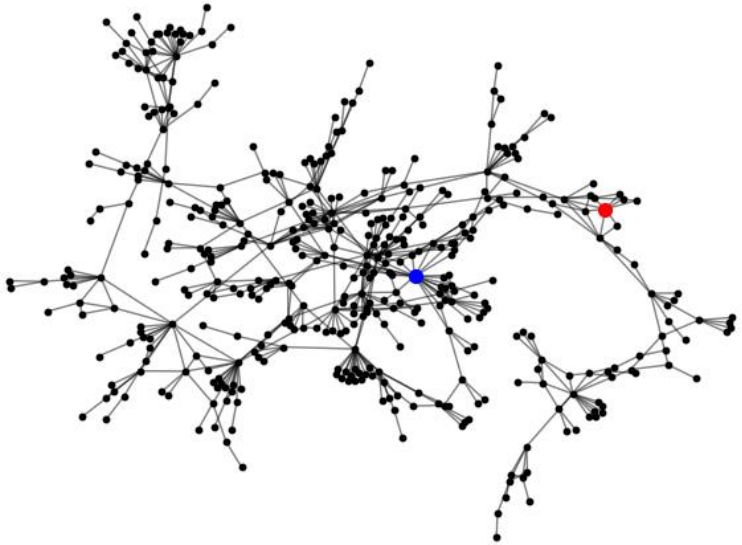
- Method for modeling fracture networks in low permeability rock
- Used to simulate fluid flow and particle transport
- Applications:
  - CO_2 sequestration
  - environmental restoration of contaminated fractured media
  - detection of low-level nuclear tests
  - hydrocarbon extraction



dfnworks
DISCRETE FRACTURE NETWORK

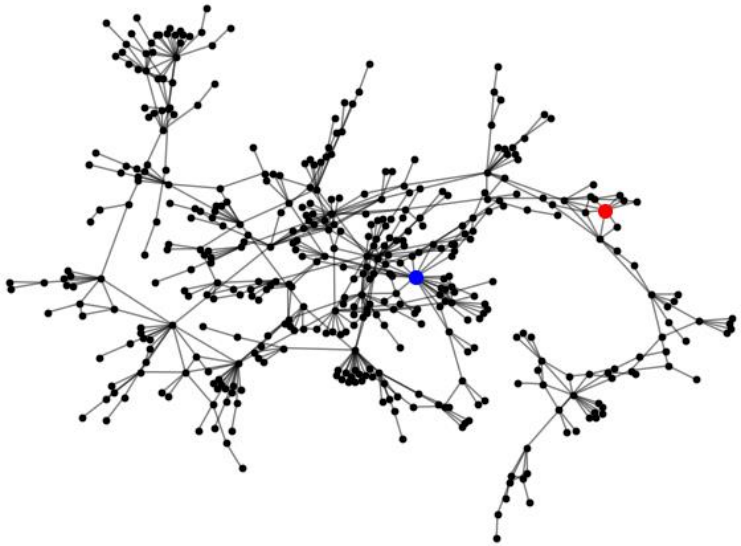
Graph Representation





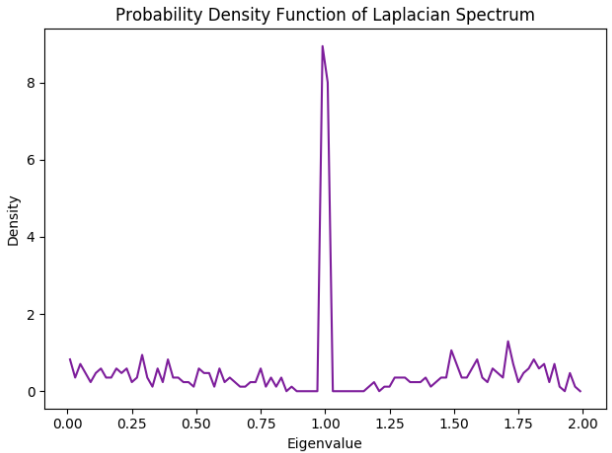
Spectral Graph Theory

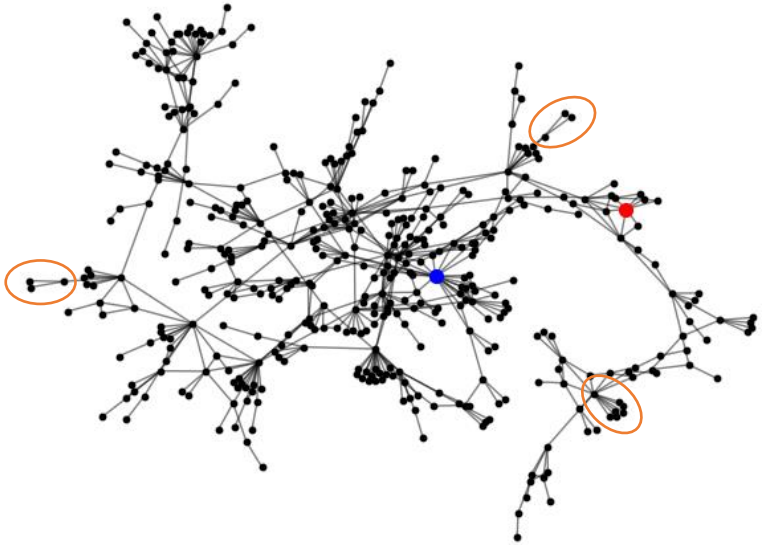
- Studies eigenvalues and eigenfunctions of matrices associated to graph
- Laplacian matrix – returns divergence of gradient of vertex weighting
- Can reveal local and global properties of graph



$$\mathcal{L}f = \lambda f$$

Spectral Graph Theory





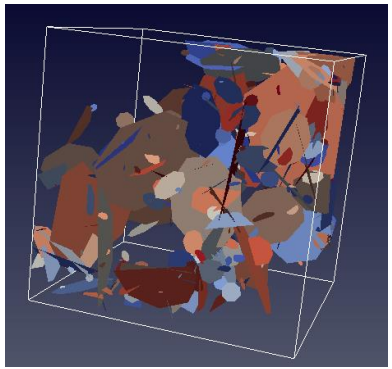
Questions

- Can we use spectral graph theory to make predictions about travel times through fracture networks?
- Can we use spectral graph theory to identify which fractures most heavily influence travel times?

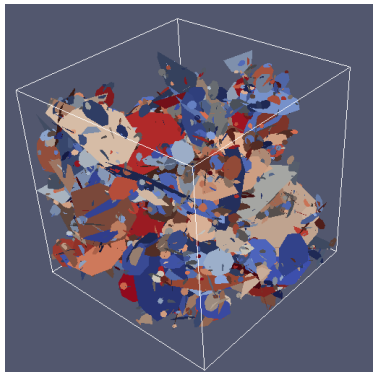
My Project

- Generate DFNs composed of discs with radii following a truncated power law

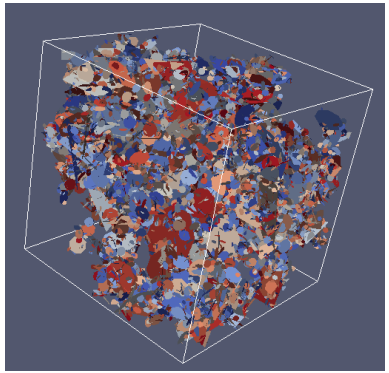
$$\frac{\alpha}{r_0}\frac{(r/r_0)^{-1-\alpha}}{1-(r_u/r_0)^{-\alpha}}$$



$\alpha = 1.25$



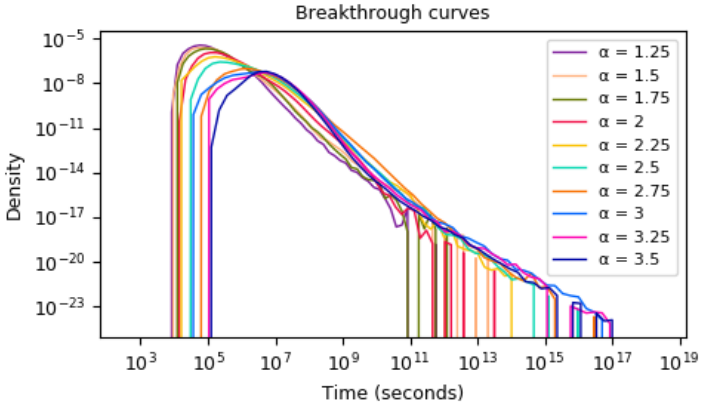
$\alpha = 2$

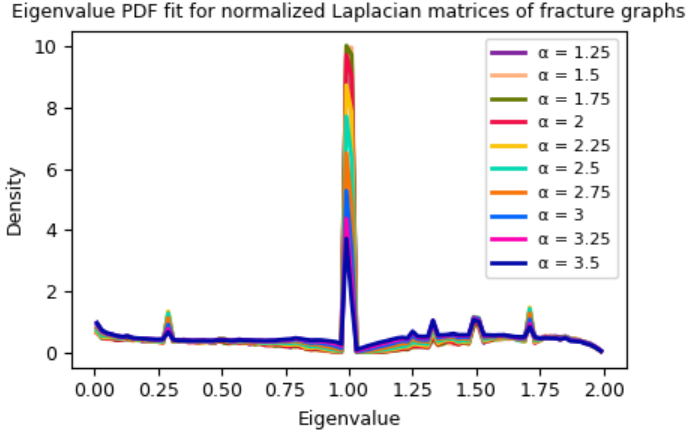


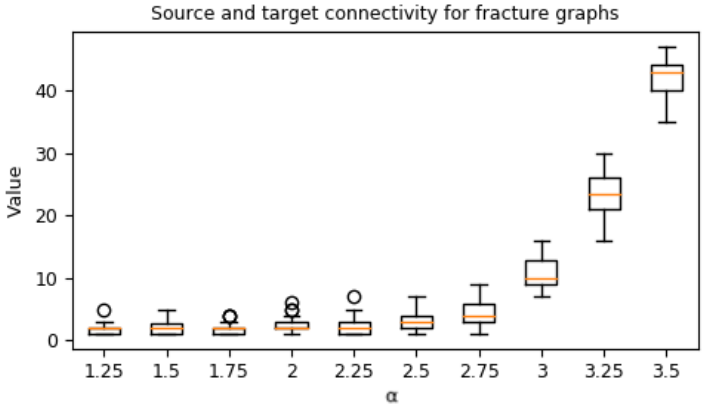
$\alpha = 2.75$

My Project

- Try to connect changes in graph spectra with breakthrough curves







Thank you!